March 14/85

Tree Condition and Pathological Evaluation of Sugar Maple Trees in Permanent Sample Plots Established in the Muskoka Area in 1984

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AQTM - NER - 03 - 85

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BACKGROUND

Reports from European countries indicate that forest decline has increased dramatically in the past few years. This widespread decline is thought to be related to air pollution, including acidic deposition. Various declines of trees in Ontario have also been observed for several decades. Some of this decline has been attributed to utilization of road salt, urbanization, disease and insect defoliations and adverse climatic conditions.

Observations of unexplained dieback of trees, particularly sugar maple, have recently become more common. In 1982, the Quebec government began investigating the cause of sugar maple decline in the Eastern Townships of that province. In 1984, the Ontario Ministry of the Environment received a request from the Ontario Ministry of Agriculture and Food to investigate the etiology of declining sugar maple trees on several maple syrup producer's woodlots in the Muskoka-Parry Sound Districts of central Ontario.

Following a preliminary site visit to the area, seven sites were selected for detailed investigation in the Muskoka area. These sites (Figure 1) included five producing maple syrup stands (Boothby, Veitch, Miller, MacLauchlan, Fincham) and two unmanaged stands (Griffiths and Gibson). An eighth site

was established for comparative purposes near Thunder Bay where the inputs of acidic precipitation are known to be considerably lower than in the Muskoka area.

At each of the study sites, sampling of the tree foliage, twigs, soil and roots was carried out. Certain trees were selected for growth analysis. The present report summarizes the data collected from the permanent plots established and from the pathological surveys carried out in conjunction with the decline study.

I PERMANENT PLOTS IN SUGAR MAPLE STANDS

A. Plot Establishment

At each of the eight study sites, permanent tree plots were established. These plots were located in a representative portion of the woodlot in proximity to the sampled trees. They were also placed to avoid interference from access trails but included trees subjected to tapping in some locations.

Square plots, 20 m per side, were laid out. The sides were oriented in north-south and east-west directions, using a compass. The corners of the plots were marked by plastic flags. All trees with a diameter of 10 cm or greater were tagged and evaluated. This included recently dead standing trees. Prenumbered PVC tags were attached to the trees with stainless steel or copper nails, 15 cm above the diameter at breast height (DBH) measurement point.

B. Evaluation of Trees

Condition ratings and physical measurements for each tree were made at the time of plot establishment. For each tree, the species, height (m) and DBH were recorded. The position of the tree within the tree canopy (dominant, codominant or understory) was recorded.

The condition of the trees was evaluated by three different methods. The first method was a scoring procedure as indicated in the form shown in Appendix A. Foliage size, colour and degree of chlorosis were assigned weighted values. Similarly, the degree of twig and branch dieback were assigned to injury classes with weighted values.

Tree trunk soundness was similarly evaluated. A total score for each tree was obtained by summing the individual scores for foliage, twig, branch and trunk condition. A perfectly healthy tree would have a score of 5 while a tree in the worst possible condition would have a score of 33.

The second evaluation method was the assessment of the tree condition on scale of 1 to 10 where 1 represented a perfectly healthy specimen tree and 10 was an intact but dead tree. The individual ratings are described below.

Crown Condition Classification System

For Coniferous and Deciduous Trees

Rating	Description
1	Near perfect specimen tree
2	High quality forest tree with self pruning of shaded branches
3	Tree in good condition, may have one or two dead branches
4	Tree in fair to moderate condition with three or more dead branches
5	Up to one half of crown dead
6	One half to 75% of crown dead
7	75 - 90% of crown dead
8	Over 90% of crown dead, some branches retaining foliage
9	Branches with few live needles/leaves still attached
10	Tree dead

The third method of tree evaluation was to directly estimate the percentage of the branches and the crown volume which had dieback, taking into account the conformation of the individual tree.

All trees were observed for the presence of other biological, mechanical or other types of disorder. These included insect feeding and evidence of tree tapping activity. The ability of the tap holes to heal satisfactorily was noted.

During the first week of September, 1984, the plots were revisited. Trees were rated individually for the development of premature fall colouration and insect injury. The scale used ranged from 0 to 7 representing the following percentages of the crown or foliage being affected.

Rating	Percent of Crown
0	0
1	0 - 1
2	1 - 5
3	5 - 10
4	10 - 20
5	20 - 35
6	35 - 50
7	> 50

C. Plot Descriptions and Species Composition

The composition of the tree stand included in each plot is shown in Table 1. The numbers of trees ranged between 21 and 28 trees per plot, except at the MacLauchlan plot where there were only 14. The other species encountered included American beech, red maple, black cherry, white ash, yellow birch and hemlock.

At most plots, the sugar maple was the predominant species by number (Table 2). The plots at Thunder Bay and MacLauchlan were composed entirely of sugar maple, but only about 20% of the trees on the plot at Gibson were sugar maples.

When fewer trees are present on the plot, each existing tree has a larger space available. The larger the available space, the less competition there will be between trees for nutrients, moisture and light, and, other things being equal, the trees on the less densely stocked sites should grow faster. The greatest available space of 28.5 m^2 per tree occurs on the MacLauchlan plot, while at the Boothby and Fincham plots, only half of this space is available for each tree.

The trees with the greatest average diameter (Table 3) are found on the MacLauchlan site, which has the most available space per tree. Beyond this, there is no apparent relationship between tree size and available space in the other plots. To determine if some other measure of tree size could be directly related to available space, the basal area and biomass of all trees within the plots was determined. The basal area was calculated according to the formula.

$$\text{Basal Area } (cm^2) = \text{Sum of } \pi\left(\frac{D}{2}\right)^2 \text{ for all trees in plot}$$

where D is tree diameter in cm

The biomass was calculated according to the equations given by Brenneman et al (1) adapted to metric measurements. The values used are shown in Appendix B. The computed total basal areas and biomass for each plot are shown in Table 4. The largest basal areas were found on the Gibson plot and on

the Thunder Bay plot. The former is composed of only 6% sugar maple. The lowest values were obtained at the Miller and MacLauchlan plots, despite the latter site having the largest trees. The highest biomass was present at Thunder Bay while the lowest was found at Griffiths. The results of this exercise failed to show a clear relationship between the tree size (diameter), total basal area or biomass and the stocking of trees on the sites. The results indicate that factors other than direct competition among the trees are influencing the volume of woody material on the study sites.

D. Tree Crown Condition

The numbers of trees within selected ranges derived from the scoring technique are presented in Table 5. If we categorize the dieback of trees with scores 0 - 10 as healthy, 11 - 15 as light, 16 - 20 as moderate and over 21 as severe, then approximately one half of the trees were healthy. About one quarter of the trees were suffering light dieback and about 20% were in the moderate class. The severe class contained about 5% of the trees in the plots.

If the scoring system is used, then the most severe plots are Miller, Thunder Bay and Boothby. The plot with the lowest score is Fincham.

The distribution of numbers of trees in the various crown class ratings are shown in Table 6. The majority of the trees are in Crown Classes 2, 3 or 4. Only about 10% of the trees are in Classes 5 or higher. Using the arithmetic mean of the ratings shows the Miller plot to be in the poorest condition followed by the Griffiths and MacLauchlan plots. The healthiest plot was the Gibson plot. The remaining four plots had identical mean rating values.

The mean percentage crown dieback ranged from 3.4 to 11.7 (Table 7). The lowest values were obtained at the Veitch and Gibson plots. The highest degree of dieback was observed at the Griffiths plot, followed by the Miller and MacLauchlan plots.

The results of the assessment methods are summarized in Table 7. A comparison of these results shows that the Miller plot had trees in the poorest condition by two methods (crown class rating and scoring) and ranked second poorest by the third method (percent dieback). The closest general agreement of methods was between the crown class rating system and the percent dieback system (correlation value $r = 0.83$) (Table 8). The correlation between the scoring method and the other two methods was very poor (correlation with crown class rating $r = 0.345$; with percent dieback $r = 0.291$).

As shown in Table 8, there was a weak but significant negative correlation ($P = 0.05$) between the percent dieback and total biomass as well as between the percent dieback and total basal area of the trees. The practical significance of these relationships is not clear.

There was a significant ($P = 0.01$) negative correlation between crown class and the total basal area. None of the correlations among the remaining parameters were statistically significant.

The numbers of trees with visible faults were determined for each plot. A fault was defined as any visible injury on the tree and included frost cracks, heart rot, tap holes, mechanical injuries, galls and sucker origin of the tree. Sucker origin was considered as a fault due to the high incidence of rot fungi spreading from the parent stump to the sucker. Approximately one half of the trees examined had one or more such faults (Table 3). The highest percentage of affected trees was noted at the Gibson plot, but since this is based on only five trees in a plot where frost cracks were prevalent, this may not be significant. The trees at the Miller and MacLauchlan sites show faults on 72 and 64% of the trees respectively. This is probably significant since the dieback problem was more conspicuous at these locations.

Table 9 includes a summary of the numbers of trees in the plots having the various types of faults. Nearly one half of the trees with faults have cracks or seams caused by frost. Fungal infections were present on about 10% of these faulted trees. Nearly equal numbers of trees (approximately 20% of the faulted trees) had heart rot, were of sucker origin, had tap holes or had other faults. Tap holes were recorded only on trees in the operational sugaring stands, but the Boothby, Miller and MacLaughlan plots were the only plots with more than one tapped tree.

E. Disorders and Injury to Tree Trunks

To determine if the presence of faults on the trees were having an effect on the dieback of the trees, the average percent crown dieback for each plot was calculated for those trees having frost cracks present, for those trees which had tap holes and for trees having any type of fault. These percentages were compared with dieback on trees having no visible fault. These data are presented in Table 10. The data are fairly consistent at all plots. When data for all plots were considered together, it was apparent that there was nearly twice as much dieback in trees with frost cracks or with any type of fault as compared with trees with no faults. Tapped trees had nearly three times as much dieback as those trees without faults.

It is apparent then that the presence of faults has contributed to the dieback of the trees. The nature of this association is not presently known, however, it would seem probable that many faults could lead to internal decay of the trees. (In some cases, the faults were diagnosed as heart rot.) In advanced stages, this decay could lead to moisture imbalances and disruption of water movement to the foliage. The health of trees in this situation would be decidedly impaired.

F. Premature Discolouration of Foliage

The distribution of numbers of trees within premature fall discolouration classes is shown in Table 11. Most plots in the Muskoka area had some premature discolouration of the tree foliage, but this is usually involved less than 10% of the tree crown. There is no readily apparent pattern of premature discolouration among the different plots. For this reason, it was believed that the discolouration rating data could be combined for living trees in all plots in the Muskoka area to increase the numbers of trees in each of the rating classes.

The relationship of premature foliage discolouration to percent dieback and tree crown class are shown in Table 12. These data show that generally more discolouration was associated with more dieback and trees in a poor condition. This trend or pattern was disrupted somewhat for trees in

discolouration class 5, where there was a moderate amount of early discolouration of the trees but only a limited amount of dieback recorded.

Table 13 shows clearly that the larger trees exhibited more of the premature foliage discolouration than the smaller trees. At the same time, the larger trees exhibited a larger percentage of dieback of the crown. The smaller trees would form the understory to codominant portion of the canopy. They would therefore be less exposed to stresses in dry periods. By contrast, the larger, exposed trees would require greater amounts of water and would be more vulnerable under drought conditions. The larger trees by virtue of their age, could have acquired a larger compliment of maladies such as heart rot, root infection and insects.

G. Insect Injury

Insect injury ratings were available for five plots (Table 14). The major insect infestation was the Maple Trumpet Skeletonizer (*Epinotia aceriella*). It was noted in all five plots that were evaluated but was most prevalent in the Fincham and Griffiths plots which are located in the same general area. Since there is no direct connection between the dieback of trees and the presence of insect injury in the current year, these data are presented for information only. By following the nature and extent of insect injury over a

period of several years, it may be possible to determine if insect infestations are having an impact on the health of the trees.

H. Condition of Secondary Species

The condition of the trees of secondary species was reviewed and is summarized in Table 15. Since the numbers of each species are relatively small, few general conclusions can be drawn. The majority of trees fell into Crown Classes 3 and 4, indicating that the trees have only minor or light dieback problems. The most notable problem with any of these trees was observed at the Gibson site where 14 out of the 18 red maple trees exhibited frost cracks on the trunks.

I. Pathological Survey

During the period of sample collection in July and September, it was possible to carry out only brief surveys of the permanent tree plots and their general area. In the course of these surveys, the presence of diseases, pests and other agents was noted but not on a systematic basis. Samples of these agents or diseased material was returned to the laboratory for identification if they could not be identified in the field. Representative specimens were photographed. The presence of organisms encountered at each of the plots is

summarized in Table 16 but should not be considered as a complete list.

A brief description of each agent is provided below, based on descriptions from Manion (2) and Rose and Lindquist (3).

a) Fungi

i) Armillariella mellea - This fungus is the agent which warrants the greatest attention of any of the diseases. It was recorded at six of the plots in the Muskoka area.

Armillariella mellea is a gilled mushroom fungus that develops most prolifically in the fall of the year. The white to tan mushroom is recognized by its white spores and a ring of veil tissue remaining on the stipe once the gills are exposed.

Armillariella mellea (Armillaria mellea) causes root rot of both hardwoods and conifers. A. mellea root rot is usually but not exclusively characterized by common association with weakened hosts. It is a contributing factor in many declines. This fungus is a sap rot fungus on dead stumps and dying trees but it is not satisfied with its saprophytic existence. Rhizomorphs (aggregates of fungus

hyphae), which look like shoe strings, move out into the soil in search of additional food. If they contact a healthy root, penetration and death of the cambium of that root may occur, thereby providing another dead root and eventually an entire root system, for its saprophytic existence.

There are very few decay fungi that can both decay xylem, like sap rot fungi, and cause the death of cambium in living trees, like parasites. This unique capacity allows A. mellea to become established as a decay fungus on weakened or dead trees and expand its sphere of influence by parasitizing and causing the death of both weakened and relatively healthy trees in the immediate vicinity. Trees infected by A. mellea develop thin, chlorotic crowns. The cambium at the base of the tree is invaded by a mycelial fan that can be readily recognized by chopping some of the bark away. Advanced infection results in the death of trees.

ii) Coriolus versicolor

Coriolus versicolor (Polyporus versicolor) is one of a large group of white rot decay fungi. The genus is characterized by annual, pored, leathery, corky or woody fruit bodies. The thin (less than

5 mm) fruit bodies have a light-coloured context. Coriolus versicolor is a small, thin, aggregating, bracket fungus with concentric zonation of grey, green, brown and black bands on the upper surface and a white pore surface. It occurs as a sap rot fungus primarily on hardwoods and is an important decay fungus of hardwood products.

iii) Eutypella parasitica

A perennial target canker occurring only on maples and sometimes confused with Nectria canker is Eutypella canker, caused by Eutypella parasitica. Eutypella canker is distinguished from Nectria canker by the characteristic black perithecia of Eutypella parasitica embedded in the bark on the canker face. The necks of the perithecia extend above the bark. Eutypella canker is evident from a mycelial fan in the cambium at the upper and lower margins of the canker, easily seen by removing the bark.

iv) Fomes fomentarius

Fomes fomentarius is a white rot fungus, with a thick, woody, perennial fruit body. Pores are very distinctive and extend 2 to 7 mm into the fruit

body. The hoof-like shape of the fruit body is somewhat characteristic. This white rotter is common on birch and beech, but also occurs on many other hardwoods. As with other sap rot fungi, the presence of fruit bodies of _F. fomentarius_ generally indicates that the tree is dead and extensively decayed.

v) _Ganoderma applanatum_

Ganoderma applanatum (_Fomes applanatus_) is an extremely common sap rot and heart rot fungus of hardwoods. The large perennial fruit bodies have a white pore surface and a smooth dark upper surface. The white rot decay is usually restricted to the lower portions of the tree and, in living trees, is often responsible for weakening the tree enough to cause it to fall over in a heavy wind.

vi) _Oxyporus populinus_

Oxyporus populinus (_Fomes connatus_) is a white rot fungus of maples. The fruit bodies are white, pored and perennial. The fruit body is often found associated with Eutypella cankers and is often covered on the upper surface with moss, giving the fruit body a green appearance. Decay of

O. populinus often results in a hollow tree of no merchantable value.

vii) *Pleurotus ulmarius*

The fungus *Pleurotus ulmarius* is most common on living wood of elm but can be found on maple, cottonwood and hickory. It often grows from the position of a branch that has been removed. The observed specimen was found growing from the top of maple stump.

viii) *Polyporus cuticularis*

Polyporus cuticularis is not common but can be found on stumps, trunks and logs of deciduous trees. It can cause either rot of the central cylinder or at wounds on the trunk of host trees.

b) Insects

i) *Cameraria aceriella* - Maple Leaf-blotch Miner

The maple leaf-blotch miner *Cameraria aceriella* is the most common of the three leaf mining species. It is found in New Brunswick to Sault Ste. Marie, Ontario, and in the northeastern United States.

Severe mining of leaves of young sugar and red maples has occurred in southern Quebec and southern Ontario.

The small flattened larvae feed in mines in the layer of cells beneath the upper surface from July to September. When feeding is completed, they change to pupae in circular flat cocoons in the mine and overwinter there. The adults are tiny reddish-brown moths with narrow silver bands across their wings.

ii) *Corythylus punctatissimus* - Pitted Ambrosia Beetle

Dying or recently dead maple trees may be attacked by many species of tiny beetles that tunnel deep in the wood. The tunnels, which go directly through the bark and into the wood, are deeply stained by the ambrosia fungus that develops in the wood on the sides of the tunnels. The fungal spores are carried by the adult beetles in special body organs found in one or both sexes depending on the species of beetle. Both the adults and the larvae may feed solely on the fungus or on both wood and fungus. In any event, there is a very close beneficial relationship between the insect and the fungus.

The pitted ambrosia beetle is primarily a pest of young trees up to 12 mm in diameter. Although the beetle will feed on many hardwood trees and shrubs in southern Canada, appreciable damage is generally confined to maple.

The beetles bore into the tree stems near ground level and tunnel deep into the wood, then form spiral tunnels that girdle the stem. The black fungal stain in the wood is a prominent feature of the tunnels.

Although the impact of the beetles on maple regeneration may appear to be of some consequence in densely stocked stands, it may also be of benefit in thinning those stands. In open stands, little mortality of young trees is reported.

iii) Epinotia aceriella - Maple Trumpet Skeletonizer

The maple trumpet skeletonizer, Epinotia aceriella, is found throughout the range of its principal host tree, sugar maple. Epidemic numbers have occurred in southern Quebec and southern Ontario. Although sugar maple appears to be the preferred species, large numbers are occasionally found on red maple.

The larvae feed on the undersurface layers of the leaf between two major veins. The larva constructs a tube of excrement and silk into which it can retreat, and covers the area around the tube with a finely woven sheet of silk. The silken canopy draws the veins together, giving the leaf a crumpled or pleated appearance.

Control measures for this insect are rarely necessary.

iv) Glycobius speciosus - Sugar Maple Borer

There have been instances, in uneven-aged stands, where large numbers of trees have been damaged by the sugar maple borer Glycobius speciosus. Although the borer can kill trees, only infrequently does it cause extensive defects in the wood. In the case of trees around homes, many of which may be under stress, feeding by these species can create unsightly scars and hasten tree decline.

On hatching, the larva tunnels through the bark to the wood surface and feeds extensively in the sapwood. Winter is passed there and feeding is resumed the following year. Extensive larval tunnels in the sapwood cause the covering bark to

die and become cracked or swollen. In old wounds the bark breaks off and the exposed wood reveals the larval tunnels. Control of the borer is difficult in the forest.

v) Vasates aceris-crumena - Maple Spindle-gall Mite

The injury to maple trees on the plots caused by mites included the maple spindle-gall *Vasates aceris-crumena* and a group of *Eriophyes* species which cause felt-like patches, called erinea, in different colours on either the upper or lower surface of the leaves of various maples. There are some variations in the life cycles of these mites, but soon after the leaf buds begin to expand, the adults move to the leaves and, feeding there, initiate abnormal cell development; as a result the female becomes enclosed in a characteristic structure. The adults leave the galls through the hairy opening and may initiate other galls as long as suitable developing tissue is present. Except in young or newly planted trees, the loss of leaf surface is generally insignificant, and control measures are unwarranted.

c) Parasitic Plants

i) *Epifagus virginiana* - Beechdrops

This species is a flowering plant that is parasitic on the roots of beech trees. The plants lack chlorophyll and the leaves are reduced to scales. In this condition, the species can not produce its own food (sugars, starch) from sunlight like green pigmented plots but has adapted its root system to extract its nutrient requirement from the host tree roots. The species is not uncommon where there are stands of American beech. Any stress to the host tree created by this parasite would be minor unles excessive numbers of plants are present.

d) Vertebrates

i) *Bos taurus* - Domestic Cattle

At one site (Miller), there was clear evidence that cattle were having an adverse effect on the forest vegetation. The evidence included feeding damage to lower branches of the trees and elimination of most of the understory vegetation. In addition, the surface soil was becoming compacted by the hooves of the cattle.

ii) _Homo sapiens_ - Humans

Human activity in some of the plots was evident as maple sap collection devices and tapping holes in the trees. The collection of sap must be regarded as parasitic, since this activity subtracts from the energy reserves of the trees. Although healthy trees can sustain an annual sap harvest, trees in an already stressed condition are less able to cope with this added stress.

The removal of dead and dying trees may have a mixed impact on the forest. Removal of wood material would reduce the plant nutrient pool on the site and may cause mechanical injury to nearby trees in the cutting process. The process would open the site to allow more sunlight to penetrate into the tree canopy and encourage the growth of subdominant and smaller trees.

II ROOT EXCAVATIONS

A. Field Sampling

At the time of the set-up of the permanent sample plots during July, several trees in a moderate to severe state of decline were selected for root sampling. The trees selected were outside of the permanent plot boundary and did not include any of the trees sampled for chemical analysis. Two trees were sampled at each of the Boothby and Miller sites, and four trees were sampled at the MacLauchlan site.

Root samples were obtained by uncovering and tracing one primary root per tree from the root buttress to the distal end or root tip. The roots generally were located within the top 30 cm of the mineral soil and ranged from about 3 to 20 m in length. The terminal portion of the root was carefully uncovered, and the soil was shaken free. The terminal section of root (about 1 m in length) was placed in polyethylene bags and returned to the laboratory in coolers.

In the laboratory, the roots were gently washed free of soil in tap water and examined. The exposed surface of the root was removed with a sterile scalpel to remove gross surface contaminants. Small wood chips were taken from the freshly exposed inner root and surface sterilized in a 10% Chlorox solution for two minutes.

The sterilized chips were then plated out on petri dishes containing commercial (Difco) potato dextrose agar (PDA). The plates were inverted and placed in the incubator at 24°C and monitored regularly for the appearance of colonies of micro-organisms. Representative colonies of the fungi developing from the root chips were subcultured and identified to genus wherever possible.

During the September visit to the Muskoka maple plots, rhizomorphs of Armillariella mellea were obtained from the roots of sample trees being felled for stem analysis or from below the bark of other sugar maple trees. At least one of the pairs of trees felled at the Griffiths, Miller, MacLauchlan, Fincham and Gibson sites had roots with Armillariella rhizomorphs and surface sterilized for two minutes in a 10% Chloxox solution. The sections were then plated out on malt extract agar (MEA) and rose bengal agar (RBA). The plates were incubated at 24°C and monitored regularly. Developing colonies of micro-organisms were identified to genus wherever possible.

B. Root Evaluation and Isolation Results

In all roots examined, the tips had died and were decayed (or had broken off due to the decay) usually back to a diameter of 3 to 5 mm. This condition was also prevalent among the secondary root branches that were obtained. Rhizomorphs of

Armillariella mellea were observed on the surface of roots of individual trees at the Miller and MacLaughlan sites.

A summary of the fungal species isolated from the roots are presented in Table 17. The most common species, _Papulospora_, was found at all sites and in four roots. Colonies of _Armillariella_ were not isolated on the media used. In all cases, the species were saprophytic or are commonly associated with decaying wood.

The results of isolations from rhizomorphs of _Armillariella mellea_ are summarized in Table 18. A fungus producing black rhizomorphs was isolated from two samples. In most cases, the isolation chip of rhizomorphs was overgrown by colonies of actimonycetes or bacteria.

III SUMMARY

Eight permanent observation tree plots were set up at seven sites in the Muskoka area and at a control site near Thunder Bay. The trees were identified and evaluated for crown condition and dieback, insects and disease, premature fall discolouration and other disorders. The data were compiled to determine what factors might be contributing to the decline and dieback of the trees. Although there was variability among plots, it was evident that larger trees showed a higher incidence of dieback of the crown and of premature fall discolouration of the foliage.

The presence of various disorders, disease and damage to the tree bole doubled the amount of dieback of the crown compared with trees without these problems. Trees which had been tapped showed nearly three times as much dieback.

A number of disease and insect problems were encountered with the most significant being *Armillariella mellea* root rot. This disease has been associated with decline of maple at other locations in North America and is a more significant problem for trees in a stressed condition, such as those created by drought or insect defoliation. Results from the present report will be utilized along with data obtained in other parts of the decline study to discover if acidic precipitation (or other atmospheric contaminants) is involved in the observed decline of maple trees.

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WDM/ml/R6-11

TABLE 1: Tree stand composition by species in permanent sugar maple plots established in the Muskoka area - 1984

Location	Sugar Maple	American Beech	Black Cherry	White Ash	Red Maple	Yellow Birch	Hemlock	Total Trees
Thunder Bay	25	-	-	-	-	-	-	25
Griffiths	17	1	3	-	-	-	-	21
Boothby	17	6	-	2	-	3	-	28
Veitch	19	1	-	-	1	1	-	22
Miller	18	-	-	-	3	-	-	21
MacLauchlan	14	-	-	-	-	-	-	14
Fincham	23	3	2	-	-	-	-	28
Gibson	5	-	-	-	18	1	2	26
Total Trees	138	11	5	2	22	5	2	185
Number of Plots	8	4	2	1	3	3	2	-

TABLE 2: Tree stand densities in permanent sugar maple plots established in the Muskoka area - 1984

Location	Trees per Plot*	Sugar Maple Trees per plot	% Sugar Maple Trees	Number of Tree Species in Plot	Available Space per Tree (m^2)
Thunder Bay	25	25	100	1	16.0
Griffiths	21	17	81	3	19.0
Boothby	28	17	61	4	14.3
Veitch	22	19	86	4	18.2
Miller	21	18	86	2	19.0
MacLauchlan	14	14	100	1	28.5
Fincham	28	23	82	3	14.3
Gibson	26	5	19	4	15.3

* Plot size is 20 m X 20 m

TABLE 3: Summary of sugar maple data coll ted in the Muskoka area - 1984

Plot Name	# Sugar Maple Trees*	Mean Dia ter (cm)	# Trees with Faults	% of Trees with Faults
Thunder Bay	25	24.6	14	56
Griffiths	17	18.8	8	47
Boothby	17	21.5	8	47
Veitch	19	20.9	9	47
Miller	18	22.0	13	72
MacLauchlan	14	27.0	10	71
Fincham	23	19.6	9	39
Gibson	5	14.8	4	80
TOTALS	138	-	75	54

* includes sample trees

TABLE 4: Basal area and mass of trees in permanent plots established in the Muskoka area - 1984

Location	Basal Area (cm^2) Total	Sugar Maple	% Sugar Maple	Dry Weight (kg) Total	Sugar Maple	% Sugar Maple
Thunder Bay	13601	13601	100	12353	12353	100
Griffiths	9696	7747	80	7717	6414	83
Boothby	11738	4139	65	9398	6701	71
Veitch	10499	7485	71	10293	7106	69
Miller	8958	8448	94	7969	7730	97
MacLauchlan	8836	8836	100	8188	8188	100
Fincham	11717	7518	64	9230	5723	62
Gibson	15044	958	6	8928	594	6

TABLE 5: Distribution of sugar maple trees within selected scoring* ranges in permanent sample plots in the Muskoka area - 1984

Location	Score Range					
	0-10	11-15	16-20	21-25	26+	Mean**
Thunder Bay	8	5	9	3	-	14.4
Griffiths	10	6	3	-	(2)	10.9
Boothby	8	5	2	1	-	14.0
Veitch	13	4	2	-	-	11.3
Miller	6	2	8	-	(2)	14.5
MacLauchlan	7	3	4	-	-	11.4
Fincham	16	7	-	-	-	8.6
Gibson	3	2	-	-	-	10.0
TOTAL	71	34	28	4	4	

* Scoring system is described in the text

** Mean value does not include dead trees shown in brackets

TABLE 6: Distribution of sugar maple trees in various crown class ratings* in permanent sample plots in the Muskoka area - 1984

	Crown Class								
Location	2	3	4	5	6	7	8	10	Mean**
Thunder Bay	-	16	9	0	0	0	0	0	3.4
Griffiths	-	8	7	3	1	0	0	2	3.8
Boothby	2	5	9	0	0	0	0	0	3.4
Veitch	0	12	7	0	0	0	0	0	3.4
Miller	0	4	10	2	0	0	0	2	(3.9)
MacLauchlan	0	6	6	2	0	0	0	0	3.7
Fincham	2	14	5	1	0	0	1	0	3.4
Gibson	0	5	0	0	0	0	0	0	3.0
TOTAL	4	70	53	8	1	0	1	4	

* Rating system is described in the text

** Does not include trees in crown class 10 (dead)

TABLE 7: Comparison of assessment methods used to evaluate maple dieback in Muskoka - 1984

Location	Method*		
	Crown Class	Scoring	Percent Dieback
Thunder Bay	3.4	14.4	5.1
Griffiths	3.8	10.9	11.7
Boothby	3.4	14.0	6.1
Veitch	3.4	11.3	3.4
Miller	3.9	14.5	9.3
MacLauchlan	3.7	11.4	8.8
Fincham	3.4	8.6	7.8
Gibson	3.0	10.0	3.8

* Methods are described in the text

TABLE 8: Correlation coefficients among parameters determined for permanent sugar maple plots established in the Muskoka area - 1984

Parameter	Available Space per Tree (m^2)	Mean Diameter (cm)	Total Biomass (kg)	Basal Area (cm^2)	% Dieback	Crown Class
Score	0.011	0.501	0.296	-0.135	0.291	0.345
Crown Class	0.542	0.509	-0.477	-0.899**	0.830**	
Percent Dieback (%)	0.403	0.194	-0.680*	-0.686*		
Basal Area (cm^2)	-0.664	-0.502	0.565			
Total Biomass (kg)	-0.399	0.228				
Mean Diameter (cm)	0.621					

* P = 0.05

** P = 0.01

TABLE 9: Summary of visible fault types observed on trees in permanent sugar maple plots in the Muskoka area - 1984

	Fault Types						
Plot	Frost Cracks and Seams	Heart Rot	Sucker Origin	Fungal Infection Cankers	Tap Holes	Other Faults	Total* Trees with Faults
Thunder Bay	9	4	3	2	0	1	14
Griffiths	8	0	0	1	0	0	8
Boothby	3	0	3	0	9	2	8
Veitch	1	5	4	0	1	2	9
Miller	4	4	5	1	5	2	13
MacLauchlan	3	3	0	2	5	1	10
Fincham	2	0	0	0	1	6	9
Gibson	4	0	0	1	0	0	4
TOTALS	34	16	15	7	21	14	75

* Total trees may not equal sum of affected trees since trees could have more than one fault

TABLE 10: Effect of faults on percent crown dieback in permanent sugar maple plots established in the Muskoka area - 1984

Location	Frost Cracks Only	Tap Holes Only	All Faults	No Faults
Thunder Bay	5.4	-	5.5	5.1
Griffiths	17.4	-	19.5	6.1
Boothby	6.7	7.2	6.1	5.5
Veitch	5.0*	10.0*	4.5	2.4
Miller	8.8	12.0	10.0	3.8
MacLauchlan	10.6	13.4	11.4	2.0
Fincham	5.0	20.0*	9.4	4.4
Gibson	3.5	-	3.5	5.0*
AVERAGE	7.8	12.5	8.3	4.3

* Values based on single trees

TABLE 11: Distribution of sugar maple trees in various premature fall discolouration classes in permanent sample plots in the Muskoka area - 1984

	Degree of Discolouration								
Location	0	1	2	3	4	5	6	7	Other
Thunder Bay	17	0	2	1	2	2	0	1	0
Griffiths	1	2	2	6	4	2	2	0	2
Boothby	-*	-	-	-	-	-	-	-	-
Veitch	1	8	5	5	0	0	0	0	0
Miller	4	3	2	3	2	2	0	0	2
MacLauchlan	3	1	2	5	1	2	0	0	
Fincham	0	5	1	6	5	5	0	0	1
Gibson	0	5	0	0	0	0	0	0	0
TOTAL TREES	26	24	14	26	14	13	2	1	

* Data not available

TABLE 12: Relationship of premature fall discolouration of foliage in premature sugar maple plots in the Muskoka area - 1984

	Discolouration Class*						
	0	1	2	3	4	5	6
Percent Dieback	3.1	2.9	3.3	11.9	14.5	5.7	17.5
Mean** Crown Class Rating	3.3	3.0	3.3	3.9	4.0	3.6	4.5

* Ratings are described in the text

** Arithmetic mean of ratings described in the text

TABLE 13: Influence of tree size on degree of dieback and premature foliage discolouration in permanent sugar maple plots established in the Muskoka area - 1984

	Tree Diameter Class (cm)					
	10-15	15-20	20-25	25-30	30-35	>35
Percent Dieback	2.8	6.0	6.4	9.6	11.5	13.3
Mean** Premature Foliage Discolouration Rating	1.1	2.5	2.4	3.0	3.5	4.1

* Percent dieback based on all living trees in six plots and foliage discolouration rating based on all living trees in five plots

** Arithmetic mean of ratings described in the text

TABLE 14: Distribution of sugar maple trees in various foliar insect injury classes in permanent sample plots in the Muskoka area - 1984

	Insect Injury Class								
Location	0	1	2	3	4	5	6	7	Other
Thunder Bay	-*	-	-	-	-	-	-	-	-
Griffiths	0	0	4	12	2	1	0	0	2
Boothby	-	-	-	-	-	-	-	-	-
Veitch	0	2	6	11	0	0	0	0	0
Miller	-	-	-	-	-	-	-	-	-
MacLauchlan	0	2	5	7	0	0	0	0	0
Fincham	0	0	3	6	7	6	0	0	1
Gibson	0	4	0	1	0	0	0	0	0

* Data not available

TABLE 15: Numbers of trees of secondary species in different crown classes* at permanent plots established in the Muskoka area - 1984

Location	Species	Crown Class 2	3	4	5	6	7	8	9	10	Total
Griffiths	Beech	1	-	-	-	-	-	-	-	-	1
	Black Cherry	-	-	2	-	1	-	-	-	-	3
Boothby	Beech	1	3	2	-	-	-	-	-	-	6
	White Ash	-	2	-	-	-	-	-	-	-	2
	Yellow Birch	-	2	1	-	-	-	-	-	-	3
Veitch	Beech	-	1	-	-	-	-	-	-	-	1
	Red Maple	-	-	1	-	-	-	-	-	-	1
	Yellow Birch	-	-	1	-	-	-	-	-	-	1
Miller	Red Maple	-	-	2	-	-	-	-	-	1	3
Fincham	Beech	1	-	2	-	-	-	-	-	-	3
	Black Cherry	-	1	1	-	-	-	-	-	-	2
Gibson	Red Maple	-	7	9	1	-	-	1	-	-	18
	Yellow Birch	-	-	-	1	-	-	-	-	-	1
	Hemlock	-	-	2	-	-	-	-	-	-	2

* Crown class ratings described in text

TABLE 16: Summary* of pests and disease organisms recorded at sugar maple study sites in the Muskoka ara - 1984

		Location						
Organism Type	Species	Griffiths	Boothby	Veitch	Miller	MacLauchlan	Fincham	Gibson
Fungi	*Armillariella mellea*	*		*	*	*	*	*
	Coriolus versicolor					*		
	Eutypella parasitica			*		*		
	Fomes fomentarius				*	*		
	Ganoderma applanatum				*	*		
	Oxyporus populinus					*		
	Pleurotus ulmarius					*		
	Polyporus cuticularis					*		
Insects	*Cameraria aceriella*				*			
	Corythylus punctatissimus	*	*	*		*	*	
	Epinotia aceriella	*		*	*	*	*	*
	Glycobius speciosus					*		
	Vasetes aceris-crumena	*		*	*	*	*	*
Parasitic Plots	*Epifagus virginiana*			*			*	
Vertebrates	*Bos taurus*				*			
	Homo sapiens		*	*	*	*	*	

* Complete inventories for all plots are not available

TABLE 17: Identification of fungal species isolated from decaying roots collected at sugar maple plot sites in the Muskoka area - 1984

Location	Tree	Decay Type	Fungal Species	Comments
Boothby	1	moist decay	Papulospora	
	2	brown-black decay, main root	Nigrospora	
			Papulospora	
Miller	1	dead root tip	Stilbum	
	2	dead root tip	Gonatobotrys	
		black rhizomorphs*	Scopulariopsis	
		black rhizomorphs*	Papulospora	
		decayed tip	unknown	
MacLauchlan	1	black rhizomorphs*	none	
	2	black decay	Helicosporium	
		fine lateral root	Aposphaeria	
	3	brownish decay	Helicosporium	
	4	black central decay	Populospora	
		black central decay	unknown	

* Black rhizomorphs of Armillariella mellea

TABLE 18: Results of isolations from rhizomorphs of *Armillariella mellea* collected at sugar maple plot sites in the Muskoka area - 1984

Location	Tree Number	Organisms Isolated Bacteria	Actimomycetes	Fungal Species
Veitch	-	+	+	Armillariella
Miller	-		+	Fusarium, Armillariella
	120		+	-
MacLauchlan	-	+		Myrothecium, unknown
	-		+	Scopulariopsis, unknown
	101		+	
Fincham	2		+	Fusarium
Gibson	174		+	unkown

APPENDIX B

Values used to compute standing tree biomass in permanent sugar maple plots established in the Muskoka area - 1984

Generalized Equation*

Biomass (lb.) = a X b where X is diameter in inches

Species	a	b
Sugar Maple	2.4439	2.5735
Red Maple	2.0072	2.5080
American Beech	2.0394	2.5715
Black Cherry	1.8082	2.6174
White Ash	2.3626	2.4798
Yellow Birch	3.1042	2.3753
Hemlock	1.3449	2.4500

Conversion factors

1 inch = 2.54 cm
1 lb. = 453.6 g

* after Brenneman B.B.; D. J. Frederick, W. E. Gardiner, L. H. Schoenhofen and P. L. Marsh. 1978. Biomass of species and stands of West Virginia hardwoods. Pope P.E. ed. Proceedings Central Hardwood Forest Conference II. West LaFayette, IN: Purdue Univ.; p. 159-178.

	DATE DUE		